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A global carbon tax to compensate damage and adaptation costs*

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Abstract

We analyze the implications of a global carbon tax on CO2 to finance the damage and adaptation costs of developing countries (DCs) using the computable general equilibrium model GEMINI-E3. We considered two options, first, that the tax is only applied to industrialized countries and secondly, that the tax is charged globally. We conclude that a scheme that puts the entire tax burden on the industrialized countries would not be a feasible policy strategy. Furthermore, it would be more likely that industrialized countries accept to finance adaptation because it entails a lower financial burden and might foster emission reductions in DCs.

JEL-Classification: C68, D58, H23, Q54

Keywords: computable general equilibrium model, climate change, global carbon tax, adaptation costs

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1. Introduction

Assessing the damages due to climate change and the adaptation measures encompassed are crucial points for the design of effective policies beyond the commitments stipulated in the Kyoto Protocol. This assessment becomes more complicated because globally the damages are unevenly distributed. In particular, developing countries (DCs) are very likely to suffer a larger part of these damages. Moreover, the financial resources needed to adapt to climate change in these countries is considerable. Estimates of the World Bank show that adaptation costs will be in the order of 75 to 100 billion per year (World Bank, 2009). These figures are equivalent to the amount transferred from industrialized countries to developed ones as foreign development aid.

The current international structure that coordinates climate policies states that industrialized countries have to help developing ones to meet the cost of adaptation (M☐öhner and Klein, 2007; Klein and Persson, 2008). Currently, under the measures enacted by the Kyoto Protocol, it is stipulated that 2% of the proceedings of every CDM project will go into an adaptation fund. Nevertheless, this measure may prove to be insufficient. Estimates show that by 2012 there will be collected only 100 to 500 million USD (M☐öhner and Klein, 2007; Klein and Persson, 2008). Financial support for developing countries then becomes an important issue for the Post-Kyoto commitment period. Particularly, the support to meet adaptation costs and to compensate a large extent of the damages from climate change is crucial to engage DCs in clear and effective mitigation strategies of greenhouse gases (GHGs).

A possible instrument to deal with this issue is a tax on CO2 emissions. This tax would generate revenues that might be used to tackle the issues of compensation of damages and adaptation costs. A tax is cost-efficient and by making CO2 emissions more costly it will ideally foster a decrease in the consumption of fossil fuels and a substitution in favor of fuels that have a lower content of carbon. Thus, at a first glance, a tax is a simple and flexible mean to internalize the costs of emissions of GHGs (Nordhaus, 2007). However, the implementation of a carbon tax is not exempt of difficulties. Among these we can distinguish the distribution of total costs (though marginal costs among countries are equalized), the replacement of existing taxes (without any further distortionary effects), the possible strategic policies from governments - i.e. lowering other taxes to counteract the increase of fossil fuels, see Hoel (1993). Furthermore, issues like enforcement and compliance, institutional control, political acceptability, and specially the allocation of the revenues, have to be considered before implementing such a scheme (Haugland et al., 1992; Aldy et al., 2003; Mankiw, 2009).[1]

The objective of this paper is to test the implications of a global carbon tax on CO2 emissions in order to help meet the damage and adaptation costs of the developing countries. To attain our objective, we use a computable general equilibrium model (CGE) to test our scenarios. We rely on the GEMINI-E3, a dynamic-recursive CGE model which represents the world economy in 28 regions and 18 sectors (Bernard and Vielle, 1998 and 2008). We test two sets of scenarios. In the first set, we

[1] For a complete description of advantages and disadvantages of an international carbon tax and the possible difficulties of its implementation see Bicchetti et al. (2007).

consider that the total tax revenue equals the sum of damage costs for DCs, and it is then redistributed only to DCs according to the estimated damages they suffer. In the second set, we consider that the total tax revenue equals the sum of adaptation costs for DCs, and it is then redistributed only to DCs according to the estimated damages they suffer. For both sets of scenarios we consider two options, first that the tax is only applied to industrialized countries (in our case represented by the OECD countries) and secondly, that the tax is charged globally.

A harmonized tax system is now a regular feature of national environmental policies (e.g. the SOx tax on the USA). However, an international tax scheme of such nature has not yet been implemented. The closest approach to a harmonized tax among different countries is the common fiscal and trade policy for the members of the European Union. The idea of an international environmental tax (especially to tackle emissions of GHGs) is not yet completely seen as viable and offers therefore great scope for analysis. The literature on harmonized global carbon taxes dates back to the studies of the early nineties such as Haugland et al. (1992) and Hoel (1993) and more recently, Cooper (2000), Nordhaus (2007) and Cramton and Stoft (2009). Haugland et al. (1992) perform an empirical analysis of the effects of policy measures (among these a carbon tax) to abate CO2 emissions. In particular, they show that a very high level of the tax is needed in order to stabilize emissions and that depending on the distribution of global energy prices a tax is not necessarily cost-effective. Hoel (1993) investigates different schemes of carbon taxes for international climate policy. First, he shows that a harmonization of domestic carbon taxes will face many difficulties and that it is unlikely that CO2 emissions will be allocated efficiently among countries. Secondly, he explains that a better alternative would be to let the participating countries pay a tax proportional to their CO2 emissions to a international agency. Cooper (2000) presents a general survey of the policy issues of climate change. He pays particular attention to the socio-economic consequences of a climate policy and the difficulties faced to engage most countries in effective abatement of GHGs. Further, he explains why a international climate policy based on national emission targets would not be effective and argue in favor of a harmonized carbon emissions tax. Nordhaus (2007) critically assesses the current climate policy making under the Kyoto Protocol. He praises the effectiveness of a harmonized carbon tax system in comparison to the current quantity based approach (i.e. fixed emission targets for each country). Nordhaus explains that the advantages of a carbon tax are clear, among these are the higher efficiency in the face of uncertainties derived from climate change, the easiness to capture revenues, less distortionary effects, and probably less opportunities for corruption and rent-seeking behavior. Cramton and Stoft (2009) analyze the economic effects of a global carbon tax allowing for a full integration with a cap-and-trade system. They find that a global carbon price of $30 per ton together with a Green Fund for equity with developing countries does not translate into major economic expenditures. They assume that the distributional effects of the instrument are based on the carbon price and a clean development incentive rate. Furthermore, by replacing national emission caps with this policy, the world oil price is reduced and there is an effective revenue transfer from oil exporters to oil importers.

Our contribution to the literature on international carbon taxes is in considering it as a mean to provide the financial resources needed to tackle the costs associated to the damages and abatements strategies to climate change. Thus, we do not focus on the incentive properties of the tax (i.e. its capacity to foster further abatement of GHGs) or on the possible distortionary effects that the tax will entail - for a discussion on this issue see Poterba (1991); Goulder (1995); and Howarth (2006). Furthermore, we focus on a tax on CO2 emissions. Previous estimates using the GEMINI-E3 model have shown that although extending such a tax to cover all GHGs will render better environmental results (i.e. higher abatement levels), its implementation will be doubtful, in particular because of the difficulty of monitoring the emission of other GHGs (such as methane) in order to calculate the adequate tax charges - for details see Bicchetti et al. (2007).

A general conclusion from our study is that a scheme that puts the entire burden on the industrialized countries either to finance damage or adaptation costs would not be a feasible policy strategy. The uneven distribution of the tax burden would not encourage the industrialized countries to engage in meaningful abatement strategies. Furthermore, we find that it is more likely that industrialized countries accept to finance adaptation because it entails a lower financial burden and might give DCs incentives to reduce their emissions. Thus, it might be easier to implement an international agreement based on a tax to finance adaptation costs. The paper is structured as follows, section 2 presents our modeling framework, the main features of the GEMINI-3 model and our reference scenario. Section 3 presents the discussion of our main results. Finally, section 4 concludes.

2. Modeling Framework

2.1 The GEMINI-E3 model

GEMINI-E3[2] is a dynamic-recursive CGE model which represents the world economy in 28 regions and 18 sectors, and contains a highly detailed representation of indirect taxation (Bernard and Vielle, 1998 and 2008). In this paper, we use an aggregated version of the model with 14 regions as listed in Table 1.

Table 1: GEMINI-E3 Regional Description

Name	Countries
EUR	European Union (25 countries)
XEU	Other European Countries
FSU	Former Soviet Union (except Baltic States)
USA	United States of America
CAN	Canada
AUZ	Australia and New Zealand
JAP	Japan
MEX	Mexico
CHI	China
IND	India
ASI	Rest of Asia
LAT	Central and Latin America
MID	Middle East
AFR	Africa

GEMINI-E3 is a Mixed Complementarity Problem (MCP) written in GAMS and solved by the PATH solver (Ferris and Munson, 2000; Ferris and Pang, 1997). GEMINI-E3 is built on a comprehensive energy-economy data set, the GTAP-6 database (Dimaranan, 2006), that provides a consistent

[2] For a complete description of the model, please refer to all technical documents available at http://www.gemini-e3.net. A GEMINI-E3 web interface is also available at http:// gemini-e3.ordecsys2.ch.

representation of energy markets in physical units, a detailed Social Accounting Matrix (SAM) for a large set of countries or regions, and bilateral trade flows between them. From the 2001 database reference year, and for the recent years, we integrate the main observed trends in the energy market such as the increase of energy prices and we improve the database with information on indirect taxation and government expenditures from the International Energy Agency (2002a,b, 2005), the Organization for Economic Co-operation and Development (2005, 2003) and the International Monetary Fund (2004). For non CO2 GHGs, data on emissions and abatement costs comes from the United States Environmental Protection Agency (2006).

Apart from a comprehensive description of indirect taxation, the model's specificity is to simulate all relevant markets: e.g. commodities (through relative prices), labor (through wages) as well as domestic and international savings (through interest rates and exchange rates). Terms of trade (i.e. real income transfers between countries resulting from variations of imports and exports relative prices) and \real" exchange rates are also accurately represented.

Time periods are linked in the model through endogenous real interest rates, which are determined by the equilibrium between savings and investments. GEMINI-E3 is a model based on recursive dynamics. Expectations of agents are based on adaptative rules and the model does not presume perfect foresight. National and regional models are linked by endogenous real exchange rates resulting from constraints on foreign trade deficits or surpluses.

GEMINI-E3 provides the following outputs for each region or country and for each year: carbon taxes, marginal abatement costs, price of tradable permits (when relevant), abatement of GHG emissions, net sales of tradable permits (when relevant) and total net welfare loss, which is also available in a disaggregated manner as net loss from terms of trade, pure deadweight loss of taxation and net purchases of tradable permits when relevant. Macroeconomic aggregates such as production, imports and final demand are also provided by the model, as well as real exchange rates, real interest rates and sectorial data such as changes in production or use of production factors.

The welfare indicator used in the paper is consumer surplus. Some authors show that for the case of a CGE Model, neither the GDP at constant prices nor households' final consumption at constant prices can provide relevant measures for the economic costs of climate change policies (Bernard and Vielle, 2003 and 2008). In effect, one | even the major | policy effect is to change relative prices, precisely in order to advocate the desirable and least costly substitutions. Any measure by an aggregate quantity at constant prices, in line with the rules of national accounting, cannot capture the very part of the welfare loss (eventually gain) resulting from this change in relative prices. Surplus provides a reliable measure by representing the effect of change in relative prices by an equivalent income loss. In particular, the sign of surplus is the same as the sign of utility change, positive if utility increases and negative if utility decreases. In order to compare surplus among countries we divide this measure by the household consumption. Thereafter, we express the welfare impact as a percentage of household consumption.

2.2 The Reference Scenario

The reference scenario (or Business as usual) quantifies the world economic and GHG emissions path up to 2050 when no energy policies occur. We use the projections of oil prices from the International Energy Outlook (Energy Information Administration, 2006a) published by the US Department of Energy (DOE). The DOE expects lower investments and oil production in key oil producing regions; this being mainly due to restrictions on access and contracting, which affect oil exploration and production costs. We assume that oil prices in 2010 are at 36 USD per barrel at 2004 prices and increase linearly to 57 USD in 2030. After 2030, oil prices rise linearly up to 69 USD per barrel in 2050. Concerning the other fossil energies, we assume an indexation of natural gas prices to oil prices of 0.5 (i.e. the price of gas increases by 5% when the oil price increases by 10%) and stability of coal prices in real USD.

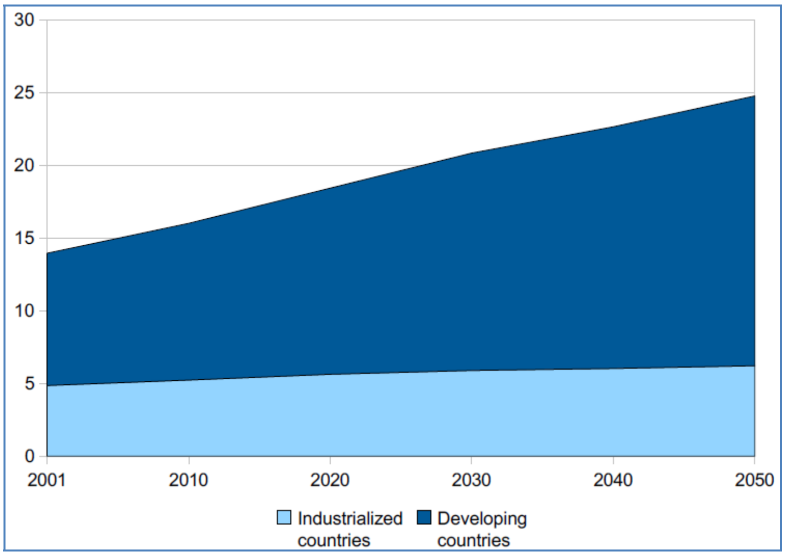

Figure 1: Reference case GHG emissions (GtC)

Reference scenario CO2 emissions, energy consumption, GDP and populations for the years 2000 to 2030, follow the projections of the Energy Information Administration (2006b) and from 2030 to 2050, we suppose annual GDP per capita growth rates that converge linearly to 2% in industrialized regions (except Japan, Canada and Australia) and to 2.5% in all other regions (including Japan, Canada and Australia).

World final energy consumption annually increases by 1.7% whereas the global annual economic growth reaches 2.8% on average over the period 2020-2050. High oil and natural gas prices make coal and electricity more competitive and attractive (Vielle and Viguier, 2007). As a result, coal consumption grows by 2.3% per year and electricity by 1.7%. Conversely, petroleum products and natural gas consumption, as a consequence of the high prices, increase only by 1% and 0.9% per year respectively.

World GHG emissions start at 9.1 gigatons of carbon (GtC) in 2001 to reach 18.5 GtC in 2050. In 2001, developing countries GHG emissions represent 47% of world emissions as can be seen in Figure 1. This share reaches respectively 56% in 2020 and 66% in 2050. The share of CO2 emissions increases slightly from 71% in 2001 to 75% in 2050 whereas the shares of nitrous oxide and high GWP gases remain stable. The proportion of methane decreases from 18% in 2001 to 15% in 2050.

3. Results and discussion

In this section, we present the results of our simulations for an international carbon tax on CO2 emissions. As we have mentioned in the introduction, we will not focus on the incentive properties of a carbon tax (i.e. on the ability to foster emissions' abatement) although the model those effects who account. Rather we will emphasize the tax as a mean to obtain a revenue that could be used either for compensating damage costs or for financing adaptation to climate change. Previous estimates using the GEMINI-E3 model (see Bicchetti et al. (2007)) have shown that considering a at world wide carbon tax rate of 15 USD2001 on CO2 emissions could induce significant emissions reduction of the order of % relative to the baseline. Moreover, when the tax is extended to consider all GHGs the results improve greatly. However, this tax scheme has some problems. First, the tax revenue is too small to compensate DCs for the damage costs due to climate change. Secondly, the enforcement and compliance with a tax on overall GHGs emissions will prove rather difficult. For instance, methane emissions (the second most important GHG after CO2) are difficult to monitor and thus the associated tax charges would be difficult to determine. As explained by Bicchetti et al. (2007), there is a certain conflict between effectiveness and targets closely related to equity issues (such as compensation from damages costs or financing adaptation).

In the following two subsections, we present the key results from our analysis. In our calculations, the GEMIN-E3 model endogenously calculates the tax rate in order to meet the revenue target (i.e. either to compensate damage costs or finance adaptation).

3.1 A tax to compensate damages costs due to climate change

Several studies have attempted to estimate damage costs due to climate change as a percentage of GDP (see table 2). Among the most recent studies, Kemfert (2005), using the WIAGEM model, predicts substantial damage costs in India and Asia in 2050 (5.89% of GDP) as well as high damage costs for China and Sub-Saharan Africa. Nordhaus and Boyer (2000), using the RICE-99 model and contrary to Kemfert, found high damage costs in Europe (2.83%). Nevertheless, their estimates for India and Sub-Saharan Africa are relatively similar (4.93% and 3.91%). The FUND model developed by Tol (2002) predicts climate change gains for the USA, Europe and Russia among others for the year 2050 with 1ffC temperature increase. However, Tol also expects substantial loss for Africa (4.10%).

Table 2: Damages Costs of Climate Change in % of GDP*

	WIAGEM[1] (2.5°C) 2050	WIAGEM[1] (2.5°C) 2100	WIAGEM[2] 2050	RICE[3] (2.5°C) 2100	FUND[4] (1°C) 2050
USA	1.13	1.22	0.67	0.45	-3.40
EU15	0.84	0.85	0.72	2.83	-3.70
Canada, New Zeal., Australia	3.13	3.55	0.76	-	-
Japan	0.61	0.59	0.69	0.50	-1.00
Russia	0.51	0.85	1.31	-0.65	-2.00
Eastern and Central Europe	0.51	0.85	1.31	0.71	-2.00
China	3.12	2.54	3.54	0.22	-2.10
India	4.85	5.49	5.89	4.93	1.70
Latin America	0.85	0.95	2.23	-	0.10
Asia	4.85	5.49	5.89	-	1.70
Mexico	0.87	1.01	-	-	-
Middle East	0.65	0.95	-	1.95	-1.10
North Africa	0.65	0.95	-	-	-
Sub-Saharan Africa	2.21	3.66	2.26	3.91	4.10
ROW	1.95	2.15	0.82	-	-

Sources: [1]Kemfert (2002), [2]Kemfert (2005), [3]Nordhaus and Boyer (2000), [4]Tol (2002)

Notes: * In the table, a positive sign denotes damages.

Recently, the Stern Review (Stern, 2007) has reported relatively high estimates based on the PAGE2002 model (Wahbaa and Hope, 2006). For the results of this subsection we assume that the tax revenue must cover those costs as reported by the Stern Review. However, some of our assumptions for the reference scenario differ from the assumptions made by the Stern Review. Therefore, we interpolate (see table 3) the results of the PAGE2002 model with respect to the temperature increase of our reference scenario. Further, for our simulations, contrary to the model version used by the Stern Review, neither balanced growth equivalents nor equity weights have been taken into account to compute the estimated damage costs for DCs. Table 3 provides the tax revenue target, which equalizes the global warming impact as percent of GDP in DCs as already mentioned.

We assume for our scenarios that the total tax revenue equals the sum of damage costs for DCs, and it is then redistributed only to DCs according to the estimated damages they suffer. Thus, the tax is set endogenously. Only the tax base varies according to the scenario considered and the tax base parameters are precisely defined for each scenario. Furthermore, given the small impact of the tax on temperature increase (< 0.1°C) found in our analysis and the large uncertainties on climate sensitivity, we do not re-estimate the damage costs when the tax is applied.

Table 3: Temperature increase and damage costs for developing countries

	2010	2020	2030	2040
Temperature increase from reference scenario	0.71	0.89	1.12	1.38
Impacts as % of GDP				
Mexico	0.20	0.25	0.31	0.39
China	0.00	0.00	0.01	0.01
India	0.83	1.04	1.30	1.61
Asia	0.83	1.04	1.30	1.61
Latin America	0.20	0.25	0.31	0.39
Middle East	0.50	0.63	0.79	0.98
Africa	0.50	0.63	0.79	0.98
Impacts in millions of USD2001				
Mexico	1 831	3 480	6 119	9 055
China	109	235	480	784
India	8 726	18 841	38 921	65 085
Asia	20 042	33 223	51 481	66 830
Latin America	4 473	7 586	13 128	18 688
Middle East	7 580	13 910	25 766	37 378
Africa	5 054	9 357	17 223	25 551
Sum	47 815	86 632	153 118	223 372

We test two scenarios. First, we consider that industrialized countries (represented by the members of the OECD) compensate DCs for the damage costs due to climate change through the revenues collected by a carbon tax on that CO2 emissions - we call this scenario OECD tax. Secondly, we analyze the setting where the carbon tax is applied worldwide - we call this scenario World tax. Although all countries pay the tax, only developing ones get a refund in the same proportion of the damages that they will suffer. Table 4 presents a summary of our results.

Table 4. Results of carbon tax to compensate climate change damages*

	OECD tax	World tax
Carbon tax in USD2001	72	25
CO2 abatement	3.60%	19.30%
Welfare impact Australia-New Zealand	-1.80%	-0.90%
Welfare impact Canada	-1.70%	-0.70%
Welfare impact Other European countries	-1.20%	-0.50%
Welfare impact USA	-0.74%	-0.40%
Welfare impact Former Soviet Union	-0.60%	-3.40%
Welfare impact China	-0.09%	-2.80%

* Notes: All are annual figures for 2040; welfare impacts are measured as percentage of household consumption; countries shown in the table are those who have the most negative welfare impacts under the two scenarios

For the OECD tax scenario, we observe from table 4 that for the impact on the abatement of CO2 emissions is modest (it is only of 3.6% annually by 2040) with a tax level of 72 USD2001 per ton of carbon. As a matter of fact, emissions are increased by 2% in developing countries. This is mainly due to the decrease in energy demand in OECD countries (as a result of higher energy prices due to the tax) that induces a decline in the international prices of energy, which implies a favorable terms-of-trade effect for developing countries that import most of their fossil fuel consumption. Moreover, the loss of competitiveness for energy intensive industries in OECD countries would lead to a relocation of some production to DCs, increasing their emissions.

It is unlikely that a tax scheme like this will be implemented. As it may be expected DCs are better off because they receive large transfers of money from OECD countries. Nevertheless, the economic burden of OECD countries could be perceived to be very high and some of them may not be willing to participate in such scheme. In table 4, we present the biggest losers (in terms of decrease of household consumption) under this scheme. In particular, the tax penalizes greatly countries like others European countries, Canada and Australia in terms of welfare. Moreover, the issue of large transfers between DCs and OECD countries may become an obstacle to the success of this tax scheme. For instance, the USA incurs a large monetary transfer and thus may be reluctant to participate.

For the world tax scenario, we observe that CO2 abatement increases substantially (up to 19.3% in 2040) because all countries participate significantly in emissions reduction efforts (though not all of them receive a compensation) at a lower tax rate of 25 USD2001 per ton of carbon. All the DCs benefit from the implementation of this tax, except for China that has a welfare loss of 2.75% of household consumption. This is a consequence of the fact that the estimated damage costs of climate change for China are rather small and that China is a positive net contributor with regard to the tax revenue; its contribution is even more important that the one from the USA. In addition, China has large fossil fuel reserves. Concerning non-DCs, all the welfare losses are modest except for FSU whose welfare decreases is 3.44%. This is mainly coming from loss of terms of trade (decrease of fossil energy prices due to the declining demand). In comparison, the world tax appears to be more effective in reducing emissions (a six-fold increase) at a lower tax rate (almost three times lower) than the OECD carbon tax. However, a global carbon tax is not exempt from problems. Countries like China and FSU may object to a scheme of this nature because they experience an important welfare loss and, moreover, China has to pay a considerable amount of transfers to other DCs.

3.2 A tax to finance adaptation costs

Setting the revenue target according to the estimated damage costs may be a bold goal since, as it has been shown, some key global players may be reluctant to take part in such an agreements. Therefore, for the scenarios analyzed in this section we set the target revenue to cover the adaptation costs. Various studies have shown that adaptation can bring numerous benefits at a lower cost - see (World Bank, 2009). Current estimates of adaptation costs vary greatly. For the sake of our analysis we assume that the adaptation costs are equal to 20% of the damage estimates (see Table 5). This threshold of 20% is a compromise between several rough estimates – see, among others, Tol et al. (1998), de Bruin et al. (2009) and World Bank (2009). Tol et al. (1998) suggest that the optimal adaptation costs lie between 7 and 25% of damage estimates, whereas de Bruin et al. (2009) finds that these costs would amount to 33% of global damages and the World Bank (2009) estimates that adaptation costs would be in the order of 75 to 100 billion USD per year. Thus, there is no coherent set of estimates for climate change adaptation as a whole, meaning that the calculations presented here are subject to much uncertainty and engage in some relatively arbitrary conventions - for a sensitivity analysis of on this issue see Bicchetti et al. (2007).

Table 5: Adaptation costs in millions of USD2001

	2010	2020	2030	2040
Mexico	366	696	1 224	1 811
China	22	47	96	157
India	1 745	3 768	7 784	13 017
Asia	4 008	6 645	10 296	13 366
Latin America	895	1 517	2 626	3 738
Middle East	1 516	2 782	5 153	7 476
Africa	1 011	1 871	3 445	5 110

Table 6 presents a summary of our results. As in the case for the tax in 3.1, we consider two scenarios. In the first scenario, we assume that only OECD countries are subject to the carbon tax and that the tax revenue is fixed to match the adaptations costs over the period 2010 to 2040 | we call this the OECD carbon tax for adaptation scenario. In the second scenario, we extend the tax base globally with the same revenue target | we call this the world carbon tax for adaptation scenario.

Table 6: Results of a carbon tax to compensate adaptation costs*

	OECD tax	World tax
Carbon tax in USD2001	13	4
Global CO2 abatement	0.90%	4.50%
Welfare impact Australia-New Zealand	-0.40%	-0.20%
Welfare impact Canada	-0.30%	-0.10%
Welfare impact Other European countries	-0.20%	-0.10%
Welfare impact USA	-0.20%	-0.10%
Welfare impact Former Soviet Union	-0.10%	-0.60%

*Notes: All are annual figures for 2040; welfare impacts are measured as percentage of household consumption; selected countries are those who have the highest most negative welfare impacts under the two scenarios

We observe from table 6, that the level for the OECD carbon tax for adaptation is very low, reaching 13 USD2001 in 2040 and the impact on emissions reduction is quite modest (less than 1%). As expected the welfare effects are relatively modest and since the tax has little impact in OECD countries we do not observe strong carbon leakage phenomena. Australia, New Zealand and others European countries are the regions that undergo the greatest emissions changes. As table 6 shows, the impact on welfare is small enough to facilitate the adoption of this carbon tax in a global framework. The USA losses only 0.20% of its welfare with respect to the baseline. China incurs in a extremely low level of welfare loss, only 0.02%, and as already pointed out in the previous simulations, India is the biggest winner since it gains 1.82% with respect to the baseline. The biggest losers are other European countries, Canada and Australia-New Zealand (with a welfare loss of 0.20%, 0.30% and 0.40% respectively).

For a world carbon tax for adaptation the results improve. By increasing the tax base, the rate is lower and efficiency is also enhanced. Since the tax is applied worldwide, effectiveness against climate change is reinforced but it still remains relatively modest (CO2 emissions abatement is 4.5% in 2040). It also allows for a very low tax rate, only 4 USD2001 per ton of carbon in 2040. The tax gives big emitters such as China and India incentives to cut back their emissions to an important extent (China reduces its emissions by 15.5% and India by 5.5%). The welfare impact is less than 1% negative for China and FSU (the latter being a large exporter of fossil energy). We may venture that this pattern of results should be broadly acceptable in the framework of an international environmental agreement. For OECD countries, the impact is quite negligible. In comparison, extending the tax to cover global emissions of CO2 provides better results than applying it only to OECD countries, thus making it a viable instrument to implement.

4. Conclusions

A large part of the damages due to climate change will fall on developing countries (DCs). Currently, it is expected that the industrialized countries will help DCs to meet the associated costs of both climate change damages and adaptation measures. A possible mean to finance this help is trough an international carbon tax on CO2 emissions. In this paper, we tested the implications (via a CGE model) of a global carbon tax on CO2 emissions sufficient help to cover the damage and adaptation costs of developing countries. Our objective addresses two questions. First, to whom will the tax be applied? We could consider taxing only industrialized countries and not taxing DCs because the economies of the latter would suffer and the effort for the industrialized countries would be acceptable. Secondly, to what purpose should the tax revenues be used? Is it to compensate damages in developing countries or to finance their adaptation to climate change?

From our study, we find that an international tax to compensate damages due to climate change would face many difficulties. First, we observe that taxing only industrialized countries will not encourage them to participate, moreover, it will not foster meaningful abatement policies in DCs (in fact these countries will increase the emissions). The economic burden supported by the industrialized countries could be perceived as too high and therefore the risk of withdrawal from any international environmental agreement that supports the tax would be significant. Second, we find that when the tax base is extended to a global carbon tax it will not guarantee that all major actors will participate in the scheme. Although such a tax will obtain significant carbon emissions reduction and it will not severely penalize industrialized countries, crucial emitters such as China and FSU would not be willing to participate in such a scheme. For these countries a global carbon tax will have pernicious effects on their welfare. Notably, FSU would suffer an important loss in its terms of trade (the loss is of about 3% of household consumption). Thirdly, we observe that finding a consensus between relevant DCs would be difficult given that the policies affect them differently. Whereas India is a winner (it receives a large amount of the revenues) with a tax applied either to OECD countries or globally, China always loses in both cases given its dependence on domestic coal and relatively lower damages from climate change. Thus, it may well be much easier to convince India to participate in global abatement efforts than China.

Concerning the tax to finance adaptation costs, we find that it might be easier that countries participate in such an international scheme for many reasons. First, we find that the welfare impact of the tax is relatively low both for industrialized countries and DCs. The target revenue is lower and thus it can be achieved at overall lower cost levels. Even countries like China or FSU, which must bear the greatest welfare losses, might be willing to participate if economic compensations (like a trade provisions or technology transfers) are offered to them in order to reduce their losses. Second, we observe that the results improve (e.g. for the level of abatement) when the tax is extended worldwide. Moreover, a relatively small global tax (of 4 USD2001 per ton of carbon) will be enough to compensate for adaptation costs worldwide. This tax, expressed in units per ton of CO2, it is very low amounting to almost 1 USD2001 per ton.

A general conclusion from our study is that a scheme that puts the entire burden on the industrialized countries either to finance damage or adaptation costs would not be a feasible policy strategy. The uneven distribution of the tax burden would not encourage the industrialized countries to engage in meaningful abatement strategies. Furthermore, we have found that it is more likely that industrialized countries accept to finance adaptation because it entails a lower financial burden and might give DCs incentives to reduce their emissions. Thus, it might be easier to implement an international agreement based on a tax to finance adaptation costs.

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